CLAIMS

We Claim:

1. A catalyst composition comprising a first metallocene compound, a second metallocene compound, at least one chemically-treated solid oxide, and at least one organoaluminum compound, wherein:

a) the first metallocene compound has the following formula:

$(X^1)(X^2)(X^3)(X^4)Zr$;

wherein (X^1) and (X^2) are independently selected from a monosubstituted cyclopentadienyl, a monosubstituted indenyl, a monosubstituted fluorenyl, or a monosubstituted, partially saturated analog thereof;

wherein each substituent on (X^1) and (X^2) is independently selected from a linear or branched aliphatic group, wherein the aliphatic group is unsubstituted or substituted, any one of which having from 1 to about 20 carbon atoms;

wherein (X^3), (X^4), and any substituent on the substituted aliphatic group on (X^1) and (X^2) are independently selected from an aliphatic group, an aromatic group, a cyclic group, a combination of aliphatic and cyclic groups, an oxygen group, a sulfur group, a nitrogen group, a phosphorus group, an arsenic group, a carbon group, a silicon group, a germanium group, a tin group, a lead group, a boron group, an aluminum group, an inorganic group, an organometallic group, or a substituted derivative thereof, any one of which having from 1 to about 20 carbon atoms; a halide; or hydrogen;

b) wherein the second metallocene compound has the following formula:

$(X^5)(X^6)(X^7)(X^8)M$; wherein

1) M is Zr;

(X^5) and (X^6) are independently selected from a substituted cyclopentadienyl, a substituted indenyl, a substituted fluorenyl, or a substituted, partially saturated analog thereof, wherein at least one of (X^5) and (X^6) is at least disubstituted; and

each substituent on (X^5) and (X^6) is independently selected from a linear or branched aliphatic group, wherein the aliphatic group is unsubstituted or substituted, any one of which having from 1 to about 20 carbon atoms;

2) M is Zr;

(X^5) and (X^6) are independently selected from a cyclopentadienyl, an indenyl, a fluorenyl, a partially saturated analog thereof, or a substituted analog thereof; and

(X^5) and (X^6) are connected by a substituted or unsubstituted bridging group comprising from 3 to 5 contiguous *ansa* carbon atoms in a chain, one end of which is bonded to (X^5) and the other end of which is bonded to (X^6); or

3) M is Hf;

(X^5) and (X^6) are independently selected from a monosubstituted cyclopentadienyl, a monosubstituted indenyl, a monosubstituted fluorenyl, or a monosubstituted, partially saturated analog thereof; and

each substituent on (X^5) and (X^6) is independently selected from a linear or branched aliphatic group, wherein the aliphatic group is unsubstituted or substituted, any one of which having from 1 to about 20 carbon atoms; and

wherein (X^7), (X^8), any substituent on (X^5), any substituent on (X^6), any substituent on the substituted aliphatic group on (X^5) and (X^6), and any substituent on the substituted bridging group connecting (X^5) and (X^6) are independently selected from an aliphatic group, an aromatic group, a cyclic group, a combination of aliphatic and cyclic groups, an oxygen group, a sulfur group, a nitrogen group, a phosphorus group, an arsenic group, a carbon group, a silicon group, a germanium group, a tin group, a lead group, a boron group, an aluminum group, an inorganic group, an organometallic group, or a substituted derivative

thereof, any one of which having from 1 to about 20 carbon atoms; a halide; or hydrogen;

c) the chemically-treated solid oxide comprises a solid oxide treated with an electron-withdrawing anion; and

d) the organoaluminum compound has the following formula:

$$Al(X^9)_n(X^{10})_{3-n};$$

wherein (X^9) is a hydrocarbyl having from 1 to about 20 carbon atoms; (X^{10}) is selected from alkoxide or aryloxide having from 1 to about 20 carbon atoms, halide, or hydride; and n is a number from 1 to 3, inclusive.

2. The catalyst composition of Claim 1, wherein the second metallocene compound has the following formula:

$$(X^5)(X^6)(X^7)(X^8)Zr;$$

wherein (X^5) and (X^6) are independently selected from a substituted cyclopentadienyl, a substituted indenyl, a substituted fluorenyl, or a substituted, partially saturated analog thereof, wherein at least one of (X^5) and (X^6) is at least disubstituted;

wherein each substituent on (X^5) and (X^6) is independently selected from a linear or branched aliphatic group, wherein the aliphatic group is unsubstituted or substituted, any one of which having from 1 to about 20 carbon atoms;

wherein (X^7), (X^8), and any substituent on the substituted aliphatic group on (X^5) and (X^6) are independently selected from an aliphatic group, an aromatic group, a cyclic group, a combination of aliphatic and cyclic groups, an oxygen group, a sulfur group, a nitrogen group, a phosphorus group, an arsenic group, a carbon group, a silicon group, a germanium group, a tin group, a lead group, a boron group, an aluminum group, an inorganic group, an organometallic group, or a substituted derivative thereof, any one of which having from 1 to about 20 carbon atoms; a halide; or hydrogen.

3. The catalyst composition of Claim 2, wherein both (X^5) and (X^6) are at least disubstituted.

4. The catalyst composition of Claim 2, wherein:

a) the first metallocene compound has the formula $(\eta^5\text{-}C_5H_4R^1)_2ZrX^{11}{}_2$, wherein R^1 in each instance is independently selected from a linear or branched aliphatic group having from 1 to about 20 carbon atoms, and wherein X^{11} in each instance is independently selected from F, Cl, Br, I, OMe, OEt, O-n-Pr, O-i-Pr, O-n-Bu, O-t-Bu, NMe_2, or NEt_2;

b) the second metallocene compound has the formula $(\eta^5\text{-}C_5H_3R^1{}_2)_2ZrX^{11}{}_2$, wherein R^1 in each instance is independently selected from a linear or branched aliphatic group having from 1 to about 20 carbon atoms, and X^{11} in each instance is independently selected from F, Cl, Br, I, OMe, OEt, O-n-Pr, O-i-Pr, O-n-Bu, O-t-Bu, NMe_2, or NEt_2;

c) the chemically-treated solid oxide is selected from fluorided alumina, chlorided alumina, bromided alumina, sulfated alumina, fluorided silica-alumina, chlorided silica-alumina, bromided silica-alumina, sulfated silica-alumina, fluorided silica-zirconia, chlorided silica-zirconia, bromided silica-zirconia, sulfated silica-zirconia, or any combination thereof; and

d) the organoaluminum compound is selected from trimethylaluminum, triethylaluminum, tri-n-propylaluminum, diethylaluminum ethoxide, tri-n-butylaluminum, disobutylaluminum hydride, triisobutylaluminum, diethylaluminum chloride, or any combination thereof.

5. The catalyst composition of Claim 2, wherein:

a) the first metallocene compound has the formula $(\eta^5\text{-}C_5H_4{}^nBu)_2ZrCl_2$;

b) the second metallocene compound has the formula $(\eta^5\text{-}C_5H_3{}^nBuR^2)_2ZrCl_2$, wherein R^2 is selected from Me, Et, n-Pr, i-Pr, n-Bu, s-Bu, i-Bu, or t-Bu;

c) the chemically-treated solid oxide is selected from fluorided alumina, chlorided alumina, sulfated alumina, fluorided silica-alumina, or any combination thereof; and

d) the organoaluminum compound is selected from trimethylaluminum, triethylaluminum, tri-n-propylaluminum, diethylaluminum ethoxide, tri-n-butylaluminum, disobutylaluminum hydride, triisobutylaluminum, diethylaluminum chloride, or any combination thereof.

6. The catalyst composition of Claim 2, wherein:

a) the first metallocene compound has the formula $(\eta^5\text{-}C_5H_4{}^nBu)_2ZrCl_2$;

b) the second metallocene compound has the formula $(\eta^5\text{-}C_5H_3{}^nBuMe)_2ZrCl_2$;

c) the chemically-treated solid oxide is selected from fluorided alumina, chlorided alumina, sulfated alumina, fluorided silica-alumina, or any combination thereof; and

d) the organoaluminum compound is selected from triethylaluminum or triisobutylaluminum.

7. The catalyst composition of Claim 1, wherein the second metallocene compound is an *ansa*-metallocene having the following formula:

$$(X^5)(X^6)(X^7)(X^8)Zr;$$

wherein (X^5) and (X^6) are independently selected from a cyclopentadienyl, an indenyl, a fluorenyl, a partially saturated analog thereof, or a substituted analog thereof; wherein (X^5) and (X^6) are connected by a substituted or unsubstituted bridging group comprising from 3 to 5 contiguous *ansa* carbon atoms in a chain, one end of which is bonded to (X^5) and the other end of which is bonded to (X^6);

wherein (X^7), (X^8), any substituent on the substituted bridging group connecting (X^5) and (X^6), any substituent on (X^5), and any substituent on (X^6) are independently selected from an aliphatic group, an aromatic group, a cyclic group,

a combination of aliphatic and cyclic groups, an oxygen group, a sulfur group, a nitrogen group, a phosphorus group, an arsenic group, a carbon group, a silicon group, a germanium group, a tin group, a lead group, a boron group, an aluminum group, an inorganic group, an organometallic group, or a substituted derivative thereof, any one of which having from 1 to about 20 carbon atoms; a halide; or hydrogen.

8. The catalyst composition of Claim 7, wherein

a) the first metallocene compound has the formula $(\eta^5\text{-}C_5H_4R^1)_2ZrCl_2$, wherein R^1 in each instance is independently selected from a linear or branched aliphatic group having from 1 to about 20 carbon atoms;

b) the second metallocene compound is selected from $[\mu\text{-}CH_2(CH_2)_nCH_2](\eta^5\text{-}9\text{-}C_{13}H_8)_2ZrX^{12}_2$, $[\mu\text{-}CH_2(CH_2)_nCH_2](\eta^5\text{-}9\text{-}C_{13}H_{16})_2ZrX^{12}_2$, $[\mu\text{-}CH_2(CH_2)_nCH_2](\eta^5\text{-}1\text{-}C_9H_6)_2ZrX^{12}_2$, $[\mu\text{-}CH_2(CH_2)_nCH_2](\eta^5\text{-}1\text{-}C_9H_{10})_2ZrX^{12}_2$, or any combination thereof,

wherein n is from 1 to 3, and

wherein X^{12}, in each occurrence, is independently selected from an aliphatic group, an aromatic group, an alkoxide group, an aryloxide group, an alkylamide group, an arylamide group, a dialkylamide group, a diarylamide group, an alkyl arylamide group, an alkylthiolate group, an arylthiolate group, or a substituted derivative thereof, any one of which having from 1 to about 20 carbon atoms; a halide; or hydrogen;

c) the chemically-treated solid oxide is selected from fluorided alumina, chlorided alumina, bromided alumina, sulfated alumina, fluorided silica-alumina, chlorided silica-alumina, bromided silica-alumina, sulfated silica-alumina, fluorided silica-zirconia, chlorided silica-zirconia, bromided silica-zirconia, sulfated silica-zirconia, or any combination thereof; and

d) the organoaluminum compound is selected from trimethylaluminum, triethylaluminum, tri-n-propylaluminum, diethylaluminum ethoxide, tri-n-

butylaluminum, disobutylaluminum hydride, triisobutylaluminum, diethylaluminum chloride, or any combination thereof.

9. The catalyst composition of Claim 8, wherein X^{12} is independently selected from F, Cl, Br, I, OMe, OEt, O-n-Pr, O-i-Pr, O-n-Bu, O-t-Bu, NMe_2, or NEt_2.

10. The catalyst composition of Claim 7, wherein:

a) the first metallocene compound has the following formula $(\eta^5\text{-}C_5H_4R^1)_2ZrCl_2$, wherein R^1 in each instance is independently selected from a linear or branched aliphatic having from 1 to about 20 carbon atoms; and

b) the second metallocene compound is selected from:

1,3-propanediylbis(η^5-9-fluorenyl)zirconium dichloride;

1,4-butanediylbis(η^5-9-fluorenyl)zirconium dichloride;

1,5-pentanediylbis(η^5-9-fluorenyl)zirconium dichloride;

1,3-propanediylbis(η^5-1-indenyl)zirconium dichloride;

1,4-butanediylbis(η^5-1-indenyl)zirconium dichloride;

1,5-pentanediylbis(η^5-1-indenyl)zirconium dichloride;

1,3-propanediylbis(η^5-9-fluorenyl)di-n-butoxyzirconium;

1,4-butanediylbis(η^5-9-fluorenyl)di-n-butoxyzirconium;

1,5-pentanediylbis(η^5-9-fluorenyl)di-n-butoxyzirconium;

1,3-propanediylbis(η^5-1-indenyl)di-n-butoxyzirconium;

1,4-butanediylbis(η^5-1-indenyl)di-n-butoxyzirconium;

1,5-pentanediylbis(η^5-1-indenyl)di-n-butoxyzirconium;

1,3-propanediylbis(η^5-9-fluorenyl)zirconium dimethyl;

1,4-butanediylbis(η^5-9-fluorenyl)zirconium dimethyl;

1,5-pentanediylbis(η^5-9-fluorenyl)zirconium dimethyl;

1,3-propanediylbis(η^5-1-indenyl)zirconium dimethyl;

1,4-butanediylbis(η^5-1-indenyl)zirconium dimethyl;

1,5-pentanediylbis(η^5-1-indenyl)zirconium dimethyl;

or any combination thereof;

c) the chemically-treated solid oxide is selected from fluorided alumina, chlorided alumina, sulfated alumina, fluorided silica-alumina, or any combination thereof; and

d) the organoaluminum compound is selected from triethylaluminum or triisobutylaluminum.

11. The catalyst composition of Claim 1, wherein the second metallocene compound has the following formula:

$$(X^5)(X^6)(X^7)(X^8)Hf;$$

wherein (X^5) and (X^6) are independently selected from a monosubstituted cyclopentadienyl, a monosubstituted indenyl, a monosubstituted fluorenyl, or a monosubstituted, partially saturated analog thereof;

wherein each substituent on (X^5) and (X^6) is independently selected from a linear or branched aliphatic group, wherein the aliphatic group is unsubstituted or substituted, any one of which having from 1 to about 20 carbon atoms;

wherein (X^7), (X^8), and any substituent on the substituted aliphatic group on (X^5) and (X^6) are independently selected from an aliphatic group, an aromatic group, a cyclic group, a combination of aliphatic and cyclic groups, an oxygen group, a sulfur group, a nitrogen group, a phosphorus group, an arsenic group, a carbon group, a silicon group, a germanium group, a tin group, a lead group, a boron group, an aluminum group, an inorganic group, an organometallic group, or a substituted derivative thereof, any one of which having from 1 to about 20 carbon atoms; a halide; or hydrogen.

12. The catalyst composition of Claim 11, wherein:

a) the first metallocene compound has the following formula $(\eta^5\text{-}C_5H_4R^1)_2ZrX^{11}_2$, wherein R^1 in each instance is independently selected from a linear or branched aliphatic group having from 1 to about 20 carbon atoms, and

X^{11} is independently selected from F, Cl, Br, I, OMe, OEt, O-n-Pr, O-i-Pr, O-n-Bu, O-t-Bu, NMe_2, or NEt_2;

b) the second metallocene compound has the following formula $(\eta^5\text{-}C_5H_4R^1)_2HfX^{11}_2$, wherein R^1 in each instance is independently selected from a linear or branched aliphatic group having from 1 to about 20 carbon atoms, and X^{11} is independently selected from F, Cl, Br, I, OMe, OEt, O-n-Pr, O-i-Pr, O-n-Bu, O-t-Bu, NMe_2, or NEt_2;

c) the chemically-treated solid oxide is selected from fluorided alumina, chlorided alumina, sulfated alumina, fluorided silica-alumina, chlorided silica-alumina, sulfated silica-alumina, or any combination thereof; and

d) the organoaluminum compound is selected from trimethylaluminum, triethylaluminum, tri-n-propylaluminum, diethylaluminum ethoxide, tri-n-butylaluminum, disobutylaluminum hydride, triisobutylaluminum, diethylaluminum chloride, or any combination thereof.

13. The catalyst composition of Claim 11, wherein:

a) the first metallocene compound has the formula $(\eta^5\text{-}C_5H_4{}^nBu)_2ZrCl_2$;

b) the second metallocene compound has the formula $(\eta^5\text{-}C_5H_4{}^nBu)_2HfCl_2$;

c) the chemically-treated solid oxide is selected from fluorided alumina, chlorided alumina, sulfated alumina, fluorided silica-alumina, or any combination thereof; and

d) the organoaluminum compound is selected from trimethylaluminum, triethylaluminum, tri-n-propylaluminum, diethylaluminum ethoxide, tri-n-butylaluminum, disobutylaluminum hydride, triisobutylaluminum, diethylaluminum chloride, or any combination thereof.

14. The catalyst composition of Claim 1, wherein the chemically-treated solid oxide comprises a solid oxide treated with an electron-withdrawing anion, wherein

the solid oxide is selected from silica, alumina, silica-alumina, aluminum phosphate, heteropolytungstates, titania, zirconia, magnesia, boria, zinc oxide, mixed oxides thereof, or mixtures thereof; and

the electron-withdrawing anion is selected from fluoride, chloride, bromide, phosphate, triflate, bisulfate, sulfate, or any combination thereof.

15. The catalyst composition of Claim 1, wherein the chemically-treated solid oxide is selected from fluorided alumina, chlorided alumina, bromided alumina, sulfated alumina, fluorided silica-alumina, chlorided silica-alumina, bromided silica-alumina, sulfated silica-alumina, fluorided silica-zirconia, chlorided silica-zirconia, bromided silica-zirconia, sulfated silica-zirconia, or any combination thereof.

16. The catalyst composition of Claim 1, wherein the chemically-treated solid oxide further comprises a metal or metal ion selected from zinc, nickel, vanadium, silver, copper, gallium, tin, tungsten, molybdenum, or any combination thereof.

17. The catalyst composition of Claim 1, wherein the chemically-treated solid oxide further comprises a metal or metal ion and is selected from zinc-impregnated chlorided alumina, zinc-impregnated fluorided alumina, zinc-impregnated chlorided silica-alumina, zinc-impregnated fluorided silica-alumina, zinc-impregnated sulfated alumina, or any combination thereof.

18. The catalyst composition of Claim 1, wherein the weight ratio of the organoalumium compound to the chemically-treated solid oxide is from about 10:1 to about 1:1,000.

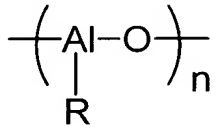
19. The catalyst composition of Claim 1, wherein the organoaluminum compound is selected from trimethylaluminum, triethylaluminum,

tripropylaluminum, diethylaluminum ethoxide, tributylaluminum, disobutylaluminum hydride, triisobutylaluminum, or diethylaluminum chloride.

20. The catalyst composition of Claim 1, further comprising an optional cocatalyst selected from at least one aluminoxane, at least one organozinc compound, at least one organoboron compound, at least one ionizing ionic compound, or any combination thereof.

21. The catalyst composition of Claim 1, further comprising an optional cocatalyst selected from at least one aluminoxane compound, wherein the aluminoxane comprises

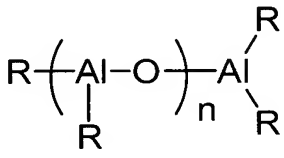
a cyclic aluminoxane having the formula:



; wherein

R is a linear or branched alkyl having from 1 to 10 carbon atoms, and n is an integer from 3 to about 10;

a linear aluminoxane having the formula:



; wherein

R is a linear or branched alkyl having from 1 to 10 carbon atoms, and n is an integer from 1 to about 50;

a cage aluminoxane having the formula $R^t_{5m+\alpha}R^b_{m-\alpha}Al_{4m}O_{3m}$, wherein m is 3 or 4 and α is = $n_{Al(3)}$ - $n_{O(2)}$ + $n_{O(4)}$; wherein $n_{Al(3)}$ is the number of three coordinate aluminum atoms, $n_{O(2)}$ is the number of two coordinate oxygen atoms, $n_{O(4)}$ is the number of 4 coordinate oxygen atoms, R^t represents a terminal alkyl group, and R^b represents a bridging alkyl group; wherein R is a linear or branched alkyl having from 1 to 10 carbon atoms; or

any combination thereof.

22. The catalyst composition of Claim 21, wherein the molar ratio of the aluminum in the aluminoxane to the combined first metallocene compound and second metallocene compound in the catalyst composition is from about 1:10 to about 100,000:1.

23. The catalyst composition of Claim 21, wherein the aluminoxane compound is selected from methylaluminoxane, ethylaluminoxane, n-propylaluminoxane, iso-propylaluminoxane, n-butylaluminoxane, t-butyl-aluminoxane, sec-butylaluminoxane, iso-butylaluminoxane, 1-pentylaluminoxane, 2-pentylaluminoxane, 3-pentylaluminoxane, iso-pentylaluminoxane, neopentylaluminoxane, or a combination thereof.

24. The catalyst composition of Claim 1, further comprising an optional cocatalyst selected from at least one organozinc compound, wherein the organozinc compound has the following formula:

$$Zn(X^{13})(X^{14});$$

wherein (X^{13}) is a hydrocarbyl having from 1 to about 20 carbon atoms; (X^{14}) is selected from a hydrocarbyl, an alkoxide or an aryloxide having from 1 to about 20 carbon atoms, halide, or hydride;

25. The catalyst composition of Claim 1, further comprising an optional cocatalyst selected from at least one organozinc compound, wherein the organozinc compound is selected from dimethylzinc, diethylzinc, dipropylzinc, dibutylzinc, dineopentylzinc, di(trimethylsilylmethyl)zinc, or any combination thereof.

26. The catalyst composition of Claim 1, further comprising an optional cocatalyst selected from at least one organoboron compound, wherein the organoboron compound is selected from tris(pentafluorophenyl)boron, tris[3,5-

bis(trifluoromethyl)phenyl]boron, *N,N*-dimethylanilinium tetrakis-(pentafluorophenyl)borate, triphenylcarbenium tetrakis(pentafluorophenyl)borate, lithium tetrakis(pentafluorophenyl)borate, *N,N*-dimethylanilinium tetrakis[3,5-bis(trifluoromethyl)phenyl]borate, triphenylcarbenium tetrakis[3,5-bis(trifluoromethyl)phenyl]borate, or a combination thereof.

27. The catalyst composition of Claim 26, wherein the molar ratio of the organoboron compound to the combined first metallocene compound and second metallocene compound in the catalyst composition is from about 0.1:1 to about 10:1.

28. The catalyst composition of Claim 1, further comprising an optional cocatalyst selected from at least one ionizing ionic compound, wherein the ionizing ionic compound is selected from tri(n-butyl)ammonium tetrakis(p-tolyl)borate, tri(n-butyl)ammonium tetrakis(m-tolyl)borate, tri(n-butyl)ammonium tetrakis(2,4-dimethyl)borate, tri(n-butyl)ammonium tetrakis(3,5-dimethylphenyl)borate, tri(n-butyl)ammonium tetrakis[3,5-bis(trifluoromethyl)phenyl]borate, tri(n-butyl)ammonium tetrakis(pentafluorophenyl)borate, N,N-dimethylanilinium tetrakis(p-tolyl)borate, N,N-dimethylanilinium tetrakis(m-tolyl)borate, N,N-dimethylanilinium tetrakis(2,4-dimethylphenyl)borate, N,N-dimethylanilinium tetrakis(3,5-dimethylphenyl)borate, N,N-dimethylanilinium tetrakis[3,5-bis(trifluoromethyl)phenyl]borate, N,N-dimethylanilinium tetrakis-(pentafluorophenyl)borate, triphenylcarbenium tetrakis(p-tolyl)borate, triphenylcarbenium tetrakis(m-tolyl)borate, triphenylcarbenium tetrakis(2,4-dimethylphenyl)borate, triphenylcarbenium tetrakis(3,5-dimethylphenyl)borate, triphenylcarbenium tetrakis[3,5-bis(trifluoromethyl)phenyl]borate, triphenylcarbenium tetrakis(pentafluorophenyl)borate, tropylium tetrakis(p-tolyl)borate, tropylium tetrakis(m-tolyl)borate, tropylium tetrakis(2,4-dimethylphenyl)borate, tropylium tetrakis(3,5-dimethylphenyl)borate, tropylium tetrakis[3,5-bis(trifluoromethyl)phenyl]borate, tropylium

tetrakis(pentafluorophenyl)borate, lithium tetrakis(pentafluorophenyl)borate, lithium tetrakis(phenyl)borate, lithium tetrakis(p-tolyl)borate, lithium tetrakis(m-tolyl)borate, lithium tetrakis(2,4-dimethylphenyl)borate, lithium tetrakis(3,5-dimethylphenyl)borate, lithium tetrafluoroborate, sodium tetrakis(pentafluorophenyl)borate, sodium tetrakis(phenyl) borate, sodium tetrakis(p-tolyl)borate, sodium tetrakis(m-tolyl)borate, sodium tetrakis(2,4-dimethylphenyl)borate, sodium tetrakis(3,5-dimethylphenyl)borate, sodium tetrafluoroborate, potassium tetrakis(pentafluorophenyl)borate, potassium tetrakis(phenyl)borate, potassium tetrakis(p-tolyl)borate, potassium tetrakis(m-tolyl)borate, potassium tetrakis(2,4-dimethylphenyl)borate, potassium tetrakis(3,5-dimethylphenyl)borate, potassium tetrafluoroborate, tri(n-butyl)ammonium tetrakis(p-tolyl)aluminate, tri(n-butyl)ammonium tetrakis(m-tolyl)aluminate, tri(n-butyl)ammonium tetrakis(2,4-dimethyl)aluminate, tri(n-butyl)ammonium tetrakis(3,5-dimethylphenyl)aluminate, tri(n-butyl)ammonium tetrakis(pentafluorophenyl)aluminate, N,N-dimethylanilinium tetrakis(p-tolyl)-aluminate, N,N-dimethylanilinium tetrakis(m-tolyl)aluminate, N,N-dimethylanilinium tetrakis(2,4-dimethylphenyl)aluminate, N,N-dimethylanilinium tetrakis(3,5-dimethylphenyl)aluminate, N,N-dimethylanilinium tetrakis (pentafluorophenyl)aluminate, triphenylcarbenium tetrakis(p-tolyl)aluminate, triphenylcarbenium tetrakis(m-tolyl)aluminate, triphenylcarbenium tetrakis(2,4-dimethylphenyl)aluminate, triphenylcarbenium tetrakis(3,5-dimethylphenyl)aluminate, triphenylcarbenium tetrakis-(pentafluorophenyl)aluminate, tropylium tetrakis(p-tolyl)aluminate, tropylium tetrakis(m-tolyl)aluminate, tropylium tetrakis(2,4-dimethylphenyl)aluminate, tropylium tetrakis(3,5-dimethylphenyl)aluminate, tropylium tetrakis(pentafluorophenyl)aluminate, lithium tetrakis(pentafluorophenyl)aluminate, lithium tetrakis-(phenyl)aluminate, lithium tetrakis(p-tolyl)aluminate, lithium tetrakis(m-tolyl)aluminate, lithium tetrakis(2,4-dimethylphenyl)aluminate, lithium tetrakis(3,5-dimethylphenyl)aluminate, lithium tetrafluoroaluminate, sodium tetrakis(pentafluorophenyl)aluminate, sodium tetrakis(phenyl)aluminate, sodium

tetrakis(p-tolyl)aluminate, sodium tetrakis(m-tolyl)aluminate, sodium tetrakis(2,4-dimethylphenyl)aluminate, sodium tetrakis(3,5-dimethylphenyl)aluminate, sodium tetrafluoroaluminate, potassium tetrakis(pentafluorophenyl)aluminate, potassium tetrakis(phenyl)aluminate, potassium tetrakis(p-tolyl)aluminate, potassium tetrakis(m-tolyl)aluminate, potassium tetrakis(2,4-dimethylphenyl)aluminate, potassium tetrakis (3,5-dimethylphenyl)aluminate, potassium tetrafluoroaluminate, or any combination thereof.

29. A catalyst composition consisting essentially of a first metallocene compound, a second metallocene compound, at least one chemically-treated solid oxide, and at least one organoaluminum compound, wherein:

a) the first metallocene compound has the following formula:

$(X^1)(X^2)(X^3)(X^4)Zr$;

wherein (X^1) and (X^2) are independently selected from a monosubstituted cyclopentadienyl, a monosubstituted indenyl, a monosubstituted fluorenyl, or a monosubstituted, partially saturated analog thereof;

wherein each substituent on (X^1) and (X^2) is independently selected from a linear or branched aliphatic group, wherein the aliphatic group is unsubstituted or substituted, any one of which having from 1 to about 20 carbon atoms;

wherein (X^3), (X^4), and any substituent on the substituted aliphatic group on (X^1) and (X^2) are independently selected from an aliphatic group, an aromatic group, a cyclic group, a combination of aliphatic and cyclic groups, an oxygen group, a sulfur group, a nitrogen group, a phosphorus group, an arsenic group, a carbon group, a silicon group, a germanium group, a tin group, a lead group, a boron group, an aluminum group, an inorganic group, an organometallic group, or a substituted derivative thereof, any one of which having from 1 to about 20 carbon atoms; a halide; or hydrogen;

b) wherein the second metallocene compound has the following formula:

$(X^5)(X^6)(X^7)(X^8)M$; wherein

1) M is Zr;

(X^5) and (X^6) are independently selected from a substituted cyclopentadienyl, a substituted indenyl, a substituted fluorenyl, or a substituted, partially saturated analog thereof, wherein at least one of (X^5) and (X^6) is at least disubstituted; and

each substituent on (X^5) and (X^6) is independently selected from a linear or branched aliphatic group, wherein the aliphatic group is unsubstituted or substituted, any one of which having from 1 to about 20 carbon atoms;

2) M is Zr;

(X^5) and (X^6) are independently selected from a cyclopentadienyl, an indenyl, a fluorenyl, a partially saturated analog thereof, or a substituted analog thereof; and

(X^5) and (X^6) are connected by a substituted or unsubstituted bridging group comprising from 3 to 5 contiguous *ansa* carbon atoms in a chain, one end of which is bonded to (X^5) and the other end of which is bonded to (X^6); or

3) M is Hf;

(X^5) and (X^6) are independently selected from a monosubstituted cyclopentadienyl, a monosubstituted indenyl, a monosubstituted fluorenyl, or a monosubstituted, partially saturated analog thereof; and

each substituent on (X^5) and (X^6) is independently selected from a linear or branched aliphatic group, wherein the aliphatic group is unsubstituted or substituted, any one of which having from 1 to about 20 carbon atoms; and

wherein (X^7), (X^8), any substituent on (X^5), any substituent on (X^6), any substituent on the substituted aliphatic group on (X^5) and (X^6), and any substituent on the substituted bridging group connecting (X^5) and (X^6) are independently selected from an aliphatic group, an aromatic group, a cyclic group, a combination of aliphatic and cyclic groups, an oxygen group, a sulfur group, a

nitrogen group, a phosphorus group, an arsenic group, a carbon group, a silicon group, a germanium group, a tin group, a lead group, a boron group, an aluminum group, an inorganic group, an organometallic group, or a substituted derivative thereof, any one of which having from 1 to about 20 carbon atoms; a halide; or hydrogen;

c) the chemically-treated solid oxide comprises a solid oxide treated with an electron-withdrawing anion; and

d) the organoaluminum compound has the following formula:

$$Al(X^9)_n(X^{10})_{3-n};$$

wherein (X^9) is a hydrocarbyl having from 1 to about 20 carbon atoms; (X^{10}) is selected from alkoxide or aryloxide having from 1 to about 20 carbon atoms, halide, or hydride; and n is a number from 1 to 3, inclusive.

30. A catalyst composition comprising the contact product of a first metallocene compound, a second metallocene compound, at least one chemically-treated solid oxide, and at least one organoaluminum compound, wherein:

a) the first metallocene compound has the following formula:

$$(X^1)(X^2)(X^3)(X^4)Zr;$$

wherein (X^1) and (X^2) are independently selected from a monosubstituted cyclopentadienyl, a monosubstituted indenyl, a monosubstituted fluorenyl, or a monosubstituted, partially saturated analog thereof;

wherein each substituent on (X^1) and (X^2) is independently selected from a linear or branched aliphatic group, wherein the aliphatic group is unsubstituted or substituted, any one of which having from 1 to about 20 carbon atoms;

wherein (X^3), (X^4), and any substituent on the substituted aliphatic group on (X^1) and (X^2) are independently selected from an aliphatic group, an aromatic group, a cyclic group, a combination of aliphatic and cyclic groups, an oxygen group, a sulfur group, a nitrogen group, a phosphorus group, an arsenic group, a carbon group, a silicon group, a germanium group, a tin group, a lead group, a boron group, an aluminum group, an inorganic group, an organometallic group, or

a substituted derivative thereof, any one of which having from 1 to about 20 carbon atoms; a halide; or hydrogen;

b) wherein the second metallocene compound has the following formula:

$(X^5)(X^6)(X^7)(X^8)M$; wherein

1) M is Zr;

(X^5) and (X^6) are independently selected from a substituted cyclopentadienyl, a substituted indenyl, a substituted fluorenyl, or a substituted, partially saturated analog thereof, wherein at least one of (X^5) and (X^6) is at least disubstituted; and

each substituent on (X^5) and (X^6) is independently selected from a linear or branched aliphatic group, wherein the aliphatic group is unsubstituted or substituted, any one of which having from 1 to about 20 carbon atoms;

2) M is Zr;

(X^5) and (X^6) are independently selected from a cyclopentadienyl, an indenyl, a fluorenyl, a partially saturated analog thereof, or a substituted analog thereof; and

(X^5) and (X^6) are connected by a substituted or unsubstituted bridging group comprising from 3 to 5 contiguous *ansa* carbon atoms in a chain, one end of which is bonded to (X^5) and the other end of which is bonded to (X^6); or

3) M is Hf;

(X^5) and (X^6) are independently selected from a monosubstituted cyclopentadienyl, a monosubstituted indenyl, a monosubstituted fluorenyl, or a monosubstituted, partially saturated analog thereof; and

each substituent on (X^5) and (X^6) is independently selected from a linear or branched aliphatic group, wherein the aliphatic group is unsubstituted or substituted, any one of which having from 1 to about 20 carbon atoms; and

wherein (X^7), (X^8), any substituent on (X^5), any substituent on (X^6), any substituent on the substituted aliphatic group on (X^5) and (X^6), and any substituent on the substituted bridging group connecting (X^5) and (X^6) are independently selected from an aliphatic group, an aromatic group, a cyclic group, a combination of aliphatic and cyclic groups, an oxygen group, a sulfur group, a nitrogen group, a phosphorus group, an arsenic group, a carbon group, a silicon group, a germanium group, a tin group, a lead group, a boron group, an aluminum group, an inorganic group, an organometallic group, or a substituted derivative thereof, any one of which having from 1 to about 20 carbon atoms; a halide; or hydrogen;

c) the chemically-treated solid oxide comprises a solid oxide treated with an electron-withdrawing anion; and

d) the organoaluminum compound has the following formula:

$$Al(X^9)_n(X^{10})_{3-n};$$

wherein (X^9) is a hydrocarbyl having from 1 to about 20 carbon atoms; (X^{10}) is selected from alkoxide or aryloxide having from 1 to about 20 carbon atoms, halide, or hydride; and n is a number from 1 to 3, inclusive.

31. A process to produce a catalyst composition comprising contacting a first metallocene compound, a second metallocene compound, at least one chemically-treated solid oxide, and at least one organoaluminum compound, wherein:

a) the first metallocene compound has the following formula:

$$(X^1)(X^2)(X^3)(X^4)Zr;$$

wherein (X^1) and (X^2) are independently selected from a monosubstituted cyclopentadienyl, a monosubstituted indenyl, a monosubstituted fluorenyl, or a monosubstituted, partially saturated analog thereof;

wherein each substituent on (X^1) and (X^2) is independently selected from a linear or branched aliphatic group, wherein the aliphatic group is unsubstituted or substituted, any one of which having from 1 to about 20 carbon atoms;

wherein (X^3), (X^4), and any substituent on the substituted aliphatic group on (X^1) and (X^2) are independently selected from an aliphatic group, an aromatic group, a cyclic group, a combination of aliphatic and cyclic groups, an oxygen group, a sulfur group, a nitrogen group, a phosphorus group, an arsenic group, a carbon group, a silicon group, a germanium group, a tin group, a lead group, a boron group, an aluminum group, an inorganic group, an organometallic group, or a substituted derivative thereof, any one of which having from 1 to about 20 carbon atoms; a halide; or hydrogen;

b) wherein the second metallocene compound has the following formula:

(X^5)(X^6)(X^7)(X^8)M; wherein

1) M is Zr;

(X^5) and (X^6) are independently selected from a substituted cyclopentadienyl, a substituted indenyl, a substituted fluorenyl, or a substituted, partially saturated analog thereof, wherein at least one of (X^5) and (X^6) is at least disubstituted; and

each substituent on (X^5) and (X^6) is independently selected from a linear or branched aliphatic group, wherein the aliphatic group is unsubstituted or substituted, any one of which having from 1 to about 20 carbon atoms;

2) M is Zr;

(X^5) and (X^6) are independently selected from a cyclopentadienyl, an indenyl, a fluorenyl, a partially saturated analog thereof, or a substituted analog thereof; and

(X^5) and (X^6) are connected by a substituted or unsubstituted bridging group comprising from 3 to 5 contiguous *ansa* carbon atoms in a chain, one end of which is bonded to (X^5) and the other end of which is bonded to (X^6); or

3) M is Hf;

(X^5) and (X^6) are independently selected from a monosubstituted cyclopentadienyl, a monosubstituted indenyl, a

monosubstituted fluorenyl, or a monosubstituted, partially saturated analog thereof; and

each substituent on (X^5) and (X^6) is independently selected from a linear or branched aliphatic group, wherein the aliphatic group is unsubstituted or substituted, any one of which having from 1 to about 20 carbon atoms; and

wherein (X^7), (X^8), any substituent on (X^5), any substituent on (X^6), any substituent on the substituted aliphatic group on (X^5) and (X^6), and any substituent on the substituted bridging group connecting (X^5) and (X^6) are independently selected from an aliphatic group, an aromatic group, a cyclic group, a combination of aliphatic and cyclic groups, an oxygen group, a sulfur group, a nitrogen group, a phosphorus group, an arsenic group, a carbon group, a silicon group, a germanium group, a tin group, a lead group, a boron group, an aluminum group, an inorganic group, an organometallic group, or a substituted derivative thereof, any one of which having from 1 to about 20 carbon atoms; a halide; or hydrogen;

c) the chemically-treated solid oxide comprises a solid oxide treated with an electron-withdrawing anion; and

d) the organoaluminum compound has the following formula:

$$Al(X^9)_n(X^{10})_{3-n};$$

wherein (X^9) is a hydrocarbyl having from 1 to about 20 carbon atoms; (X^{10}) is selected from alkoxide or aryloxide having from 1 to about 20 carbon atoms, halide, or hydride; and n is a number from 1 to 3, inclusive.

32. A process for polymerizing olefins in the presence of a catalyst composition, comprising contacting the catalyst composition with at least one type of olefin monomer, wherein the catalyst composition comprises a first metallocene compound, a second metallocene compound, at least one chemically-treated solid oxide, and at least one organoaluminum compound, wherein:

a) the first metallocene compound has the following formula:

$(X^1)(X^2)(X^3)(X^4)Zr$;

wherein (X^1) and (X^2) are independently selected from a monosubstituted cyclopentadienyl, a monosubstituted indenyl, a monosubstituted fluorenyl, or a monosubstituted, partially saturated analog thereof;

wherein each substituent on (X^1) and (X^2) is independently selected from a linear or branched aliphatic group, wherein the aliphatic group is unsubstituted or substituted, any one of which having from 1 to about 20 carbon atoms;

wherein (X^3), (X^4), and any substituent on the substituted aliphatic group on (X^1) and (X^2) are independently selected from an aliphatic group, an aromatic group, a cyclic group, a combination of aliphatic and cyclic groups, an oxygen group, a sulfur group, a nitrogen group, a phosphorus group, an arsenic group, a carbon group, a silicon group, a germanium group, a tin group, a lead group, a boron group, an aluminum group, an inorganic group, an organometallic group, or a substituted derivative thereof, any one of which having from 1 to about 20 carbon atoms; a halide; or hydrogen;

b) wherein the second metallocene compound has the following formula:

$(X^5)(X^6)(X^7)(X^8)M$; wherein

1) M is Zr;

(X^5) and (X^6) are independently selected from a substituted cyclopentadienyl, a substituted indenyl, a substituted fluorenyl, or a substituted, partially saturated analog thereof, wherein at least one of (X^5) and (X^6) is at least disubstituted; and

each substituent on (X^5) and (X^6) is independently selected from a linear or branched aliphatic group, wherein the aliphatic group is unsubstituted or substituted, any one of which having from 1 to about 20 carbon atoms;

2) M is Zr;

(X^5) and (X^6) are independently selected from a cyclopentadienyl, an indenyl, a fluorenyl, a partially saturated analog thereof, or a substituted analog thereof; and

(X^5) and (X^6) are connected by a substituted or unsubstituted bridging group comprising from 3 to 5 contiguous *ansa* carbon atoms in a chain, one end of which is bonded to (X^5) and the other end of which is bonded to (X^6); or

3) M is Hf;

(X^5) and (X^6) are independently selected from a monosubstituted cyclopentadienyl, a monosubstituted indenyl, a monosubstituted fluorenyl, or a monosubstituted, partially saturated analog thereof; and

each substituent on (X^5) and (X^6) is independently selected from a linear or branched aliphatic group, wherein the aliphatic group is unsubstituted or substituted, any one of which having from 1 to about 20 carbon atoms; and

wherein (X^7), (X^8), any substituent on (X^5), any substituent on (X^6), any substituent on the substituted aliphatic group on (X^5) and (X^6), and any substituent on the substituted bridging group connecting (X^5) and (X^6) are independently selected from an aliphatic group, an aromatic group, a cyclic group, a combination of aliphatic and cyclic groups, an oxygen group, a sulfur group, a nitrogen group, a phosphorus group, an arsenic group, a carbon group, a silicon group, a germanium group, a tin group, a lead group, a boron group, an aluminum group, an inorganic group, an organometallic group, or a substituted derivative thereof, any one of which having from 1 to about 20 carbon atoms; a halide; or hydrogen;

c) the chemically-treated solid oxide comprises a solid oxide treated with an electron-withdrawing anion; and

d) the organoaluminum compound has the following formula:

$$Al(X^9)_n(X^{10})_{3-n};$$

wherein (X^9) is a hydrocarbyl having from 1 to about 20 carbon atoms; (X^{10}) is selected from alkoxide or aryloxide having from 1 to about 20 carbon atoms, halide, or hydride; and n is a number from 1 to 3, inclusive.

33. The process of Claim 32, wherein the catalyst composition is contacted with ethylene and at least one other olefin selected from 1-butene, 2-butene, 3-methyl-1-butene, isobutylene, 1-pentene, 2-pentene, 3-methyl-1-pentene, 4-methyl-1-pentene, 1-hexene, 2-hexene, 3-hexene, 3-ethyl-1-hexene, 1-heptene, 2-heptene, or 3-heptene.

34. The process of Claim 32, wherein the catalyst composition is contacted with ethylene and 1-hexene.

35. The process of Claim 32, wherein the catalyst composition is contacted with ethylene.

36. A polymer or copolymer of ethylene, wherein the melt index is from about 0.3 to about 2.0 dg/min; the density from about 0.94 to about 0.91 g/cm^3; the CY-a parameter is from about 0.45 to about 0.70; the polydispersity index (M_w/M_n) is from about 2 to about 6; the HLMI/MI ratio is from about 16.5 to about 25; the Elmendorf MD tear resistance is greater than about 150 g for 1 mil blown film; the Elmendorf TD tear resistance is greater than about 350 g for a 1 mil blown film; the film haze is less than about 25% for a 1 mil blown film; the Dart impact strength is greater than about 600 g for a 1 mil blown film; and the Spencer impact strength is greater than about 0.7 J for a 1 mil blown film.

37. A polymer or copolymer of ethylene, wherein the melt index is from about 0.5 to about 1.5 dg/min; the density is from about 0.935 to about 0.915 g/cm^3; the CY-a parameter is from about 0.50 to about 0.65; the polydispersity index (M_w/M_n) is from about 2.2 to about 5.0; the HLMI/MI ratio is from about 17 to about 24; the Elmendorf MD tear resistance is greater than about 200 g for a 1 mil blown film; the Elmendorf TD tear resistance is greater than about 380 g for a 1 mil blown film; the film haze is less than about 15% for a 1 mil blown film; the

Dart impact strength is greater than about 800 g for a 1 mil blown film; and the Spencer impact strength is greater than about 0.9 J for a 1 mil blown film.

38. A polymer or copolymer of ethylene, wherein the melt index is from about 0.8 to about 1.3 dg/min; the density is from about 0.925 to about 0.915 g/cm^3; the CY-a parameter is from about 0.55 to about 0.62; the polydispersity index (M_w/M_n) is from about 2.6 to about 4.0; the HLMI/MI ratio is from about 17.5 to about 23; the Elmendorf MD tear resistance is greater than about 250 g for a 1 mil blown film; the Elmendorf TD tear resistance is greater than about 450 g for a 1 mil blown film; the film haze is less than about 10% for a 1 mil blown film; the Dart impact strength is greater than about 1200 g for a 1 mil blown film; and the Spencer impact strength is greater than about 1.00 J for a 1 mil blown film.